

CLAIMS:

1. An image processing device comprising:

a light source configured to irradiate a light intensity-modulated at a modulation
5 frequency to a target space;

a light receiving element configured to receive the light reflected from an object in
the target space and generate an electrical output corresponding to an intensity of
the received light; and

an image generator configured to generate a distance image having pixel values,
10 each of which provides a distance value between the object and the image
processing device, in accordance with a phase difference between the light emitted
from said light source and the light received by said light receiving element, and a
gray image having pixel values, each of which provides a gray value of the object, in
accordance with the intensity of the received light.

2. The image processing device as set forth in claim 1, further comprising:

a differentiator configured to generate a distance differential image having pixel
values, each of which provides a distance differential value, from said distance
20 image, and a gray differential image having pixel values, each of which provides a
gray differential value, from said gray image; and

an outline extractor configured to extract an outline of the object by use of said
distance differential image and said gray differential image.

3. The image processing device as set forth in claim 2, wherein said outline
extractor extracts, as the outline of the object, a region(s) where said distance
differential value maximizes in said distance differential image, and a region(s)
where said gray differential value maximizes in said gray differential image.

4. The image processing device as set forth in claim 2, wherein said outline extractor determines a first region(s) where said distance differential value maximizes in said distance differential image, and a second region(s) where said gray differential value maximizes in said gray differential image, and then extracts a corresponding region(s) between said first region(s) and said second region(s) as the outline of the object.

5. The image processing device as set forth in claim 2, wherein said outline extractor extracts, as the outline of the object, at least one of a region(s) where said distance differential value is not smaller than a threshold value in said distance differential image, and a region(s) where said gray differential value is not smaller than a threshold value in said gray differential image.

6. The image processing device as set forth in claim 2, wherein said outline extractor determines a weighted sum of said distance differential value of each of said pixels of said distance differential image and said gray differential value of a corresponding pixel of said gray differential image, and then extracts a region(s) where the weighted sum is not smaller than a threshold as the outline of the object.

7. The image processing device as set forth in claim 1, wherein said image generator generates said gray image in a time-series manner, and the image processing device further comprises a differentiator configured to generate a gray differential image having pixel values, each of which provides a gray differential value, from said gray image, and an object detector configured to detect the object

by use of said gray differential value and said distance value.

8. The image processing device as set forth in claim 7, wherein said object detector
5 generates a difference image between a pair of gray differential images, which are
generated from two gray images obtained at different times, extracts a region(s)
where each of pixel values is not smaller than a threshold value in said difference
image, and then detects said region(s) as the object when a representative value of
the pixel values of said distance image corresponding to said region(s) is within a
10 predetermined range.

9. The image processing device as set forth in claim 7, wherein said object detector
generates a plurality of difference images, each of which is a difference between two
15 of at least three gray differential images generated from at least three gray images
obtained at different times,
extracts a region(s) where each of pixel values is not smaller than a threshold value
with respect to each of said difference images to obtain binary images, performs a
logical operation between each of pixel values of one of said binary images and a
20 corresponding pixel value of another one of said binary images to extract a
common region(s) therebetween, and
detects said common region(s) as the object when a representative value of the
pixel values of said distance image corresponding to said common region(s) is
within a predetermined range.

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10. The image processing device as set forth in claim 1, further comprising:
a measuring-point determining unit configured to determine a plurality of
measuring points on the object in said gray image generated by said image
30 generator; and

a distance calculator configured to calculate an actual distance between two of said measuring points of the object by use of the distance value of the pixel corresponding to each of said measuring points in said distance image generated by said image generator.

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11. The image processing device as set forth in claim 10, further comprising:
a shape estimating unit configured to estimate a 3D shape of the object from at least one of said distance image and said gray image generated by said image generator; and

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a volume estimating unit configured to estimate a volume of the object in accordance with outputs of said shape estimating unit and said distance calculator.

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12. The image processing device as set forth in claim 10, further comprising a monitor configured to display said gray image generated by said image generator, and wherein said measuring-point determining unit comprises a position designator configured to allow a user to appoint desired measuring points on the object displayed on said monitor by touching a screen of said monitor, and said distance calculator calculates the actual distance between two of the desired measuring points appointed by said position designator.

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13. The image processing device as set forth in claim 10, further comprising an object extractor configured to extract the object having a predetermined shape from the gray image generated by said image generator, and wherein said measuring-point determining unit determines a plurality of measuring points on the object extracted by said object extractor, and said distance calculator calculates the actual distance between two of the plurality of measuring points.

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14. The image processing device as set forth in claim 1, further comprising:
a reference-pixel detector configured to detect, as a reference pixel, the pixel having
5 a minimum distance value in a predetermined region in said distance image;
a pixel extractor configured to set a specific region including said reference pixel in
said distance image, and extract a group of pixels each having the distance value
within a predetermined range from said specific region; and
an exposure controller configured to control a sensitivity of said light receiving
10 element in accordance with the gray image having the pixels, each of which has a
one-to-one correspondence with one of the pixels extracted by said pixel extractor.

15. The image processing device as set forth in claim 14, wherein a lower limit of
15 said predetermined range is the distance value of said reference pixel, and an
upper limit of said predetermined range is determined by adding a required value
to the distance value of said reference pixel.